Sagittal Gait Analysis in Children and Young Adults With Cerebral Palsy Before and After Single Event Multilevel Surgery :

A Comparative Study

From

Dr Marina Clarice Selvi Rassou
Plot No 42, 3rd Main Road,
River View Colony,
Manapakkam, Chennai-600125
Phone 9894256348

To

The Controller of Examinations,
The Tamilnadu Dr M.G.R Medical University,
Chennai
600032

Respected Madam,

(**Sub**: ***Submission of dissertation***, ***One Time Measure, MD Physical Medicine and Rehabilitation, 2011***)

Iam herewith submitting 4 copies (bound volumes) and 2 CDs of my dissertation entitled, "***Sagittal Gait Analysis in Children and Young Adults With Cerebral Palsy Before and After Single Event Multilevel Surgery-A Comparative Study"*** along with a fee of Rs one thousand five hundred, as per the regulations of the university. I hereby declare that the above thesis is a genuine work done by me.

Thanking you

Sincerely yours

Dr Marina Clarice Selvi Rassou

Reg No:20109017

Sagittal Gait Analysis in Children and Young Adults With Cerebral Palsy Before and After Single Event Multilevel Surgery-A Comparative Study”

DR Marina Clarice Selvi Rassou

Reg No: 20109017

Sagittal Gait Analysis in Children and Young Adults With Cerebral Palsy Before and After Single Event Multilevel Surgery :

A Comparative Study

Dissertation Submitted To The, Tamilnadu Dr M.G.R. Medical University, In Partial Fulfillment Of Requirements For The MD Physical Medicine And Rehabilitation (Exclusive One Time Measure 2011)

Acknowledgement

I consider it a great privilege to be able to help families and individuals with developmental disabilities of which Cerebral Palsy is the commonest. Iam thankful for Prof Suranjan Bhattacharji whose kindness, skill and vision has influenced thousands of people. His encouragement helped me take this task up. I appreciate the Gait Lab staff of Christian Medical College Vellore and thank them for their undaunted courage and perseverance that has resulted in meticulous data collection. Mr Ganesh and Mr. Richard Chillman, have guided me in my understanding of the entire exercise of Gait Ananlysis and data collection. Iam grateful to Dr Ashish Macaden, who in the midst of his busy schedule agreed to share his pioneering experience in this field to guide me. He has also helped with data analysis.

Finally, I would like to thank the entire Physical Medicine and Rehabilitation team at Christian Medical College Vellore, for their lives of sacrifice and courage, which they have dedicated "*to serve and not to be served".* Iam yet to see a people like you!

Contents

Introduction

Cerebral Palsy (CP) is the most common pediatric neurologic disorder, with an incidence of 3.6 per 1000 live births. It is defined as a motor disorder resulting from a non-progressive lesion or injury to the developing brain (1). CP being a syndrome with multiple disabilities has always been a challenge to treat. Of the various domains that may need addressing to ensure optimal function, mobility seems to play a key role in overall enhancement of quality of life in persons enduring CP. The best available evidence indicates that people with mobility impairment are among the least physically active groups in society (2). Physical and Occupational Therapies, Serial POP Casting, Medication, Orthosis and surgical procedures are in practice to work on posture, tone and mobility of persons with CP. Single Event Multilevel Surgery has replaced multi event multiple surgeries spread over a period of time. This ongoing evolution in the management of CP is primarily due to quantitative assessment tools of which Instrumented Gait Analysis is a major player. Our aim was to compare data from sagittal gait analysis of children with spastic diplegia, triplegia and hemiplegia who had undergone Single Event Multilevel Surgery, as a part of management of gait abnormalities, between 2001 and 2006 at The Christian Medical College Vellore, India.

Justification

Cerebral Palsy (CP), is the commonest developmental and neurological disease encountered in physiatric practice. A comprehensive interdisciplinary approach is required in diagnosis and management of CP. With the advent of unlimited access to medical literature through the internet, families of children with CP are increasingly aware of the most recent advances in the management of the illness.

With the overcrowding of medical literature with newer and attractive remedies for the management of developmental disorders such as CP, there is a potential danger of contempt for useful procedures such as Single Event Multilevel Surgery. Unavailability of objective evidence in favor of time tested treatment modalities due to lack of systematic scientific research, will cause funds and attention being diverted to more expensive techniques. The author is not against newer methods. However considering the fact that in spite of advances in early detection and management strategies, the incidence of CP and the burden of the handicap on families has not decreased with time, more effort needs to be made in accumulating and publishing evidence for existing management methods.

Our hope is to find a permanent prevention strategy to eradicate CP and yet in the meantime maximize on the availability of evidence based, good medical practice to reduce impairment, optimize function and aid full participation of individuals with CP in the community.

Aims and Objectives

Primary Aim

- To compare the sagittal gait parameters of Instrumented Gait Analysis, prior to and after Single Event Multilevel surgery in children and young adults with Cerebral Palsy

Secondary Aim

- To look for objective evidence for the efficacy of Single Event Multilevel Surgeries in the management of the progressive musculoskeletal disease in Cerebral Palsy.
- To initiate the availability of a database of objective gait parameters for reference and future studies in the appropriate management of musculoskeletal issues in Cerebral Palsy.

Review of Literature

Cerebral Palsy

Definition and Historical Review

Cerebral Palsy (CP) is a collection of diverse syndromes characterized by disorders of movement and posture caused by a non-progressive injury to the immature brain (3). It is a static encephalopathy that may be defined as a non progressive disorder of posture and movement, often associated with epilepsy and abnormalities of vision and intellect resulting from a defect or lesion of the developing brain. (4).

However the International Workshop on Definition and Classification of CP in 2007, to update the existing definition and Classification agreed upon the following

"Cerebral Palsy describes a group of permanent disorders of the development of movement and posture, causing activity limitation, that are attributed to non-progressive disturbances that occurred in the developing fetal or infant brain. The motor disorders of cerebral palsy are often accompanied by disturbances of sensation, perception, cognition, communication and behavior, by epilepsy and by secondary musculoskeletal problems"(5).

CP was originally described by William John Little in 1862 and hence referred to as Little's Disease (6) (7). In his monograph he describes, what we would today call spastic diplegia and attributes it to lack of oxygen at birth. Sigmund Freud in his classic 1897 text, *Infantile Cerebral Palsy*, emphasized the existence of associated problems such as epilepsy, mental retardation and visual problems. He opined that Little's disease should have probably started much before birth. Freud wrote *"Difficult birth, in certain cases, is merely a symptom of deeper effects that influence the development of the fetus."*This was widely disagreed upon till in the 1980s it was found that though perinatal asphyxia could lead to CP, it was not the sole causative factor. 8 to 28% of children with perinatal asphyxia developed CP (8).

Modern imaging techniques are making it possible to characterize the nature and location of the brain impairments that underlie CP, and with increasing precision to link the timing and location of specific impairments to particular phases of intrauterine development(9) . It has therefore become possible to recognize that many people with CP have impairments in brain structure (and almost certainly in brain function) (10) prior to their delivery. In fact it is likely that a significant proportion of people who have CP experience perinatal difficulties *secondary* to pre-existing CNS difficulties that make perinatal and immediate adaptations challenging. These new insights into the timing of the insults to brain formation are important to parents, to the accoucheurs who have traditionally been blamed for obstetrical failures, and to neurobiologists seeking to understand brain ontogeny in order to prevent the developmental problems that underlie CP and related disabilities from occurring.

Neuromusculoskeletal Pathology of Cerebral Palsy

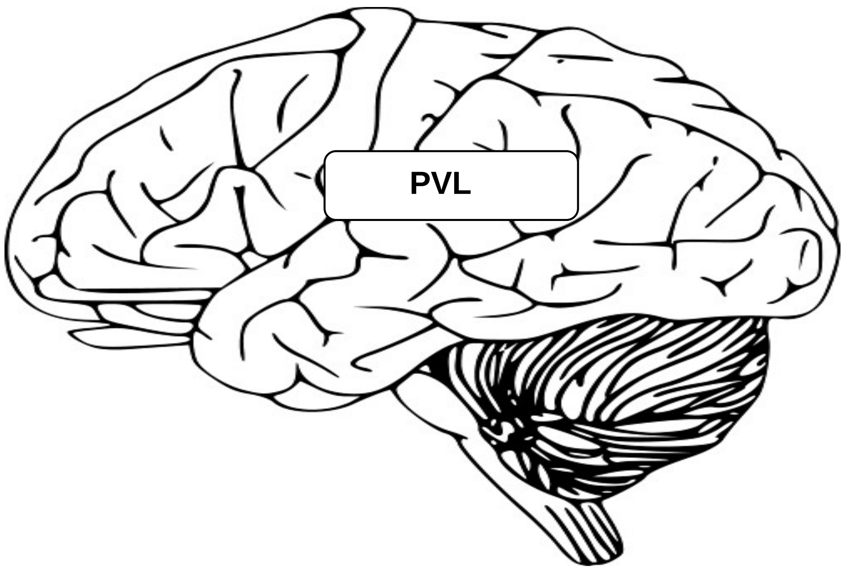
CP is non-progressive neurological condition described as a “*static encephalopathy*”, however the musculoskeletal pathology is progressive in most children. It is inappropriate to emphasize that the cerebral lesion is static without clearly stating that the musculoskeletal pathology will be progressive (11).

THE POSITIVE AND NEGATIVE FEATURES OF UPPER MOTOR NEURON SYNDROME

Cerebral palsy is the commonest cause of upper motor neuron syndrome (UMN) in children. The UMN syndrome has positive features such as spasticity, hyper-reflexia, co-contraction, and negative features including weakness, loss of selective motor control, sensory deficits and poor balance. Clinicians have traditionally focused more on the positive features because it is possible to treat spasticity, but it is the negative features which determine the locomotor prognosis (11). Fig3:1 demonstrates the sequence of musculoskeletal pathology in CP.

FIG 3:1

CNS Pathology



Loss of Inhibition

LMN

Loss of connection to

LMN

Positive features of UMN Syndrome

Spasticity,

Hyper-reflexia

Clonus

Co- contraction

Negative features of UMN Syndrome

Weakness

Fatigability

Poor Balance

Sensory Deficit

Musculoskeletal Pathology

Muscle Shortening

Bony Torsion

Joint instability

Degenerative Arthritis

The most important pathological feature of the progressive musculoskeletal pathology is a failure of longitudinal growth of skeletal muscle. An apt orthopedic synonym for CP is '*short muscle disease'* (11). The normal muscle grows due to regular stretching under conditions of physiological loading, when it is relaxed. Spasticity in Children with CP prevents the skeletal muscle from relaxing during activity and also greatly reduces the levels of activity due of muscle weakness and poor balance.

Contractures result due to imbalance between growth of long bones and the muscle tendon unit. This has been demonstrated in animal models by Ziv et al (12) and further confirmed by Cosgrove and Graham (13).

Failure to address the increase in tone (positive UMN sign), weakness, poor balance and hence reduced mobility leads to contractures, torsion of long bones and joint instability (14)(15). This predisposes to further challenges in mobility due to early degenerative changes and pain (16).

Classification of Cerebral Palsy

CP is traditionally classified by motor type and topographical distribution. A classification based on **motor type** (17) might include the terms

- **Spastic**
- **Dyskinetic**
- **Ataxic**
- **Hypotonic**

- **Mixed**

The most commonly used terms in the classification based on **topographical distribution** are (17),

- **Hemiplegia**
- **Diplegia**
- **Quadriplegia**
- **Triplega**

These classification systems were unreliable and deficient in enabling communication. Moreover they are based on impairment of body structure (topography) and function (motor).

In 2001 The World Health Organization Published the **International Classification of Functioning**, Disability and Health (ICF) for member states to use to standardize health and disability data worldwide.(18)

The ICF describes disability and dysfunction in 3 different levels

- **Impairment of body structure or function**
- **Limitation of activities**
- **Restriction of participation**

The classifications based on motor type and topographical distribution confirm with the impairment of body structure and function in the ICF but fail to address limitation in activity and participation**.**

In the year 1997, a hallmark paper was published by Palisano and colleagues that provided the **Gross Motor Function Classification Scale** (GMFCS), based on activity limitation (19). The GMFCS for the first time provided orthopedic surgeons, therapists and pediatricians with a common language to describe children with CP (17). The expanded and revised GMFCS (2007) (20) includes an age band for youth 12 to 18 years of age and emphasizes the concepts inherent in the World Health Organization's International Classification of Functioning, Disability and Health (ICF) (18). The Validity and reliability of the GMFCS-ER has been demonstrated in multiple studies. It classifies gross motor function on a five point ordinal scale with descriptions provided for 5 age groups: less than 2 years, 4to 6 years, 6 to 12 years and 12 to 18 years. Fig 2, Fig 3

In general the levels are as follows

Level 1: Walks without limitations

Level ll : Walks with limitation

Level lll: Walks with hand held mobility devise

Level lV: Self mobility with limitations, may use powered mobility.

Level V: Transported in a manual wheel chair

The GMFCS has proved to be useful in the various studies to determine age of peak motor function in cp, categorizing patients for orthopedic prognostic and experimental studies.

THE FUNCTIONAL MOBILITY SCALE

The Functional Mobility Scale was designed by Graham and colleagues as a measure of ambulatory performance in children with cp (21). The FMS is unique in that it can score mobility in three distances representing home, school and community Fig 3:4.

Table 3:1 The Functional Mobility Scale (21)

Walking Distance	Rating (1-6)
Walking 5 metres	
Walking 50 metres	
Walking 50 metres	

1. Use wheelchair, stroller or buggy: May stand for transfer and do some stepping supported by another person or using walker/frame
2. Uses K- Walker or other walking frame: without help from another person
3. Uses two crutches: without help from another person
4. Uses one crutch or two sticks without help from another person.
5. Independent on level surfaces: does not use walking aid or need help from another person.
6. Independent on all surfaces does not need help from another person when walking running and climbing stairs.

Fig3:4 Courtesy Kerr Graham Royal Children’s Hospital Melbourne

Rating **6**

Independent on all surfaces:

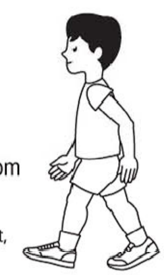
Does not use any walking aids or need any help from another person when walking over all surfaces including uneven ground, curbs etc. and in a crowded environment.

Rating **5**

Independent on level surfaces:

Does not use walking aids or need help from another person.* Requires a rail for stairs.

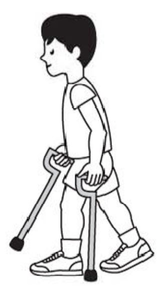
*If uses furniture, walls, fences, shop fronts for support, please use 4 as the appropriate description.



Rating **4**

Uses sticks (one or two):

Without help from another person.

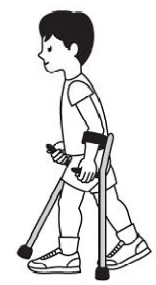


Walking distance	Rating: select the number (from 1–6) which best describes current function
5 metres (yards)	
50 metres (yards)	
500 metres (yards)	

Rating **3**

Uses crutches:

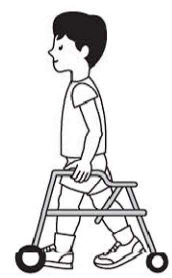
Without help from another person.



Rating **2**

Uses a walker or frame:

Without help from another person.



Rating **1**

Uses wheelchair:

May stand for transfers, may do some stepping supported by another person or using a walker/frame.

Rating **C**

Crawling:

Child crawls for mobility at home (5m).

Rating **N**

N = does not apply:

For example child does not complete the distance (500 m).

Ambulation in Cerebral Palsy

An individual with cerebral palsy cannot take a normal activity like walking for granted. The best available evidence indicates that people with mobility impairment are among the least physically active groups in society (2). The pathological condition that affects the Central Nervous System in CP causes progressive musculoskeletal abnormalities, affecting gait progressively.

CLASSIFICATION OF GAIT PATTERNS IN CEREBRAL PALSY

There is a wide need felt by researchers to describe the complexities of gait in spastic disorders. Winter *et al* in 1987 described spastic hemiplegic gait and Sutherland and Davis in 1993 described spastic hemiplegic knee motion.

HEMIPLEGIC CP GAIT

Can be divided into four types based on sagittal plane kinematics.(22)

TYPE 1 HEMIPLEGIA

In type 1 there is a ‘drop foot’ which is seen during the swing and not the stance phase. There is no calf contracture and management is with AFOs.

TYPE 2 HEMIPLEGIA

The common type encountered in clinical practice. There is true equines in stance with knee in neutral or recurvatum and hip in extension

Early stages can be managed with Botulinium injections to the calf followed by AFOs. Tendo Achilles lengthening or Strayers calf lengthening are required if contractures prevail.

TYPE 3 HEMIPLEGIA

This type is characterized by equinus, flexed and stiff knee. Management include Tendo Achilles and hamstring lengthening with AFOs post op.

TYPE 4 HEMIPLEGIA

There is marked proximal involvement. In the sagittal plane there is equinus, flexed stiff knee and the hip is adducted and internal rotated while there is an anterior tilt of the pelvis. Management includes botulinium toxin at multiple sights, surgery to release the hip adductors Illiopsoas and external rotation osteotomy of the femur.

Gait Patterns In Spastic Diplegia

TRUE EQUINUS

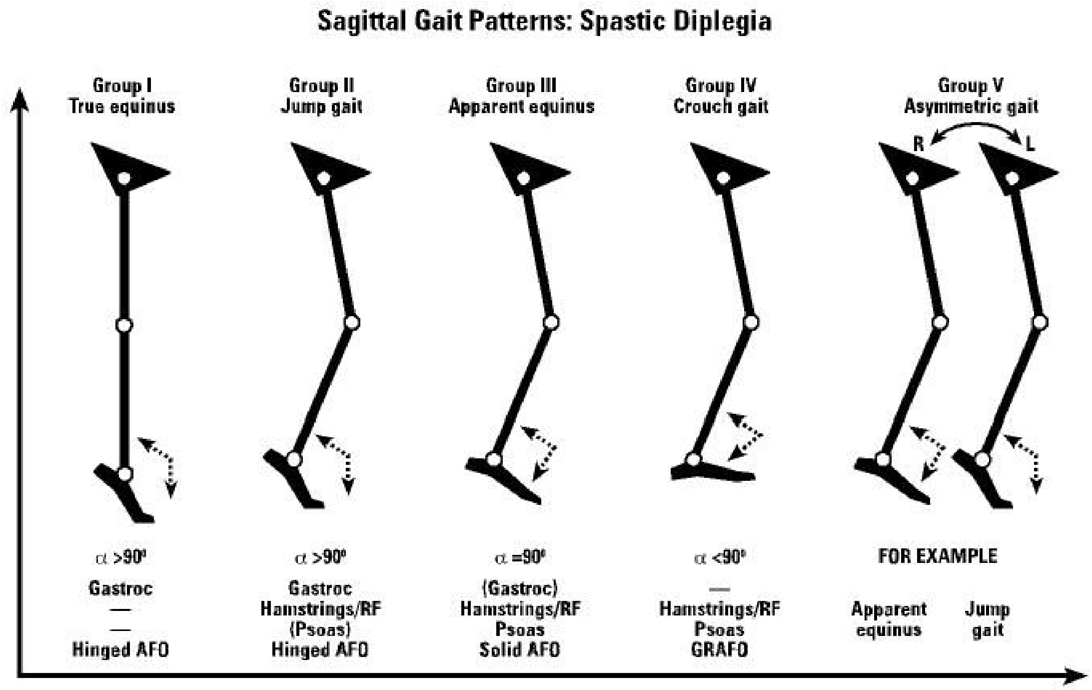
Younger children with spastic diplegia as they start to walk have a true equinus or a plantigrade foot with a recurvatum at the knee.

JUMP GAIT

Ankle in equinus, knee in flexion and stiff due to Rectus Femoris tightness. Commonly seen in spatic diplegic children.

APPARENT EQUINUS

The child seems to walk on toes yet the ankle angle is less than or equal to 90 degrees. This ensues after the jump gait and is often misinterpreted as jump gait itself. Instrumented Gait analysis helps in isolating apparent equinus. Fig: 3:5.



The pattern of knee involvement was described by Sutherland and Davids (23) and modified by Rodda J M *et al.* **Fig 5 :** Courtesy of Rodda J M Royal Children's Hospital Parkville Australia

CROUCH GAIT

Crouch gait is defined as excessive dorsiflexion or calcaneus at the ankle in combination with excessive flexion at the knee and hip.(24). Crouch gait is a part of the progressive musculoskeletal pathology recognized in CP, predominantly in the diplegic and total body involvement type. It is precipitated by isolated tenotomies at the heel coerd. Once the heel cord has been lengthened, if the spasticity or contracture of the hamstrings and iliopsoas has not been recognized and is not managed adequately, there will be a rapid increase in hip and knee flexion (25). The result is an unattractive, energy expensive gait pattern, followed by anterior knee pain and patellar pathology in adolescence (24). Fig3: 5

ORTHOPEDIC SURGICAL INTERVENTION IN CEREBRAL PALSY

Historical Review

Percutaneous tenotomy of the Achilles tendon was the first orthopaedic operation, introduced in the early part of the 19th Century in Germany by Louis Stromeyer. WilliamJohn Little who himself was a beneficiary of the above surgery for a club foot deformity he suffered from, introduced it in the United Kingdom. Ever since surgical intervention to correct deformity and reduce spasticity have been practiced.

Evolution of Single Event Multilevel Surgeries

A key development in strategic thinking of how to manage fixed musculoskeletal deformity in cerebral palsy has been the move from single level surgery, repeated at frequent intervals throughout childhood, to single event multilevel surgery (SEMLS). (26) Single level surgery at various stages of growth on various anatomical levels of the child, followed by hospitalization and casting for weeks together and physical therapy regimes to counter the weakness caused by these surgeries, left the child in hospital for long periods of time. This was described as the '*birthday syndrome'* by Rang.(27). Moreover the *"lever arm disease"* characterized by torsional deformities of long bones and joint instabilities leading to poor biomechanics of the limb and inefficient functioning of the already compromised musculotendinous unit had to be tackled. The concept of lever arm deformities has been articulated by Gage and others and includes torsional deformities of long bones, typically medial femoral torsion and lateral tibial torsion as well as joint instability including hip displacement and mid foot breaching (28).

The concept of Single Event Multilevel Surgery (SEMLS) had long been felt all over the world though it was Rang who articulated it. Reports of SEMLS was first published in 1985 (29) though the work was started in 1975. The outcome measures of the intervention were not objective as could be expected of the era, were Gait analysis and validated functional scales were not available.

The first ever study to be published with an objective outcome measure (30) was in 1993 by Nene and colleagues who used the Physiological Cost Index (PCI)of gait in children as a measure to look for changes prior to and after SEMLS.

Gage later on compared computerized gait analyses (31) of children pre and post multilevel surgery.

<u>The Common SEMLS procedures Include:</u>

- Intramuscular psoas tenotomy
- Adductor tenotomy
- Fractional lengthening of the hamstrings
- Transfer of the rectus femoris.
- Gastrocsoleus lengthening
- Femoral osteotomies
- Tibial osteotomies
- Subtalar arthrodesis
- Triple arthrodesis.

GAIT ANALYSIS

HISTORICAL CONSIDERATIONS

Aristotle (384–322 BC) can be attributed with the earliest recorded comments regarding the manner in which humans walk (32). Muybridge contributed to the understanding of movement with his famous sequential photographs of horses (33). The advent of video cameras and force plates have revolutionized Bernstein initiated kinematic studies using photographic studies. Shwartz and co-workers studied the forces generated by floor foot interface during walking.

The incorporation of Electromyography (EMG) in gait analysis was done by Inman and colleagues at the University of California Biomechanics Laboratory.(34) for simultaneous recording of activities of multiple muscle groups during ambulation.

Presently computerized gait analysis has revolutionized recording and retrieval of data for analysis.

STUDY OF NORMAL GAIT

Gait is a complex process and hence its study requires stratification to simplify this. Gait study can thus be split into (courtesy: Ganesh T, Bhuvaneshwar N, Chilman R, Tharion G, Devasahayam S, Bhattacharji S, Gait Analysis : an Overview)

QUALITATIVE a) Observational (clinical) gait analysis

b) Video gait recording and analysis

QUANTITATIVE c) Kinematic analysis

d) Kinetic analysis

e) Ambulatory EMG

f) Energy cost of ambulation

A Modern computerized system can simultaneously record all the quantitative data thus simplifying the study of gait.

OBSERVATIONAL GAIT ANALYSIS

Observational clinical and observational video gait analysis requires a basic knowledge of the normal gait cycle and the pathological variants expected.

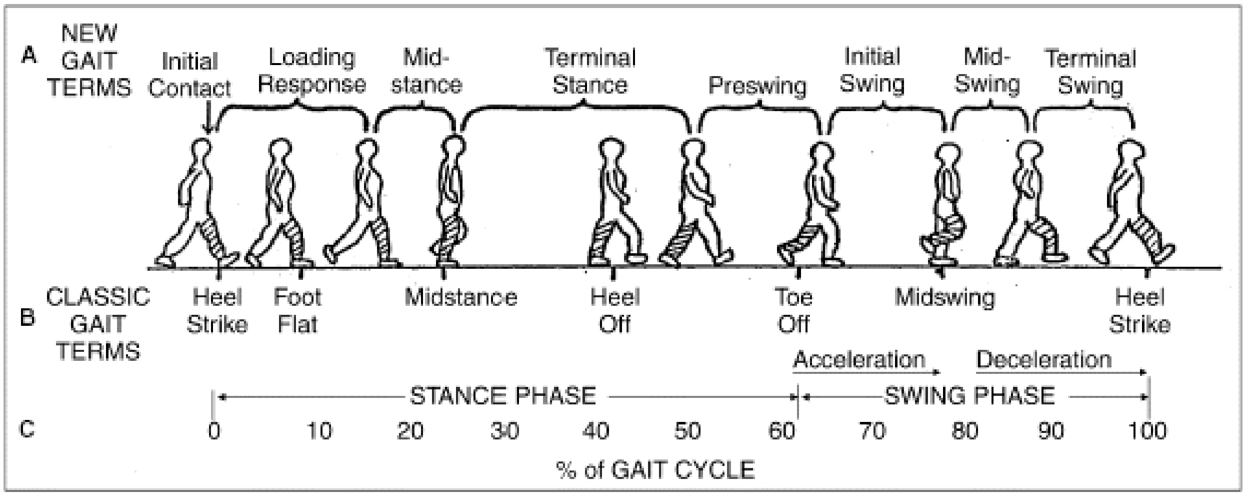
NORMAL HUMAN GAIT

Normal human gait is the repetition of a basic sequence of limb movements that serve to advance the body along a desired path while maintaining weight bearin stability conserving energy and absorbing shock of floor impact.(35)

The gait cycle is defined as the time from ipsilateral heel strike to ipsilateral heel strike and must accomplish three basic **functional tasks (35)**

- .Weight Acceptance
- Single Limb Support
- Swing Limb Advancement

- FIG3:6 Gait Cycle: **A:** New Gait Terms. **B:** Classic Gait Terms. **C:** The normal distribution of time during the gait cycle at normal walking speed. (Illustration courtesy of Carson Schneck, M.D.)



In order to critically observe gait eight **sub phases** have been described by Jacqueline Perry namely (Fig3:6)

- Initial Contact
- Loading response
- Mid Stance
- Terminal Stance
- Pre Swing
- Initial Swing
- Mid Swing
- Terminal Swing

Weight Acceptance

Single Limb Support

Swing Limb Advancement

The Range of motion of the hip, knee and ankle in sagittal plane at each sub phase can be observed and the execution of the corresponding functional tasks can be commented upon.

Clinicians analyzing gait need to be accustomed to the gait cycle.

Video Gait analysis allows for repeated viewing of the gait events and various joints and the head arm and trunk segments in detail.

QUANTITATIVE GAIT ANALYSIS

Quantitative gait analysis includes the kinematic, kinetic, ambulatory EMG and energy efficiency measure.

Kinematic Analysis:

This describes the spatial movement of the joints and limb segments. Observational gait analysis provides with qualitative kinematic analysis whereas quantitative kinematic data is provided by instrumented gait analysis.

Kinetic Analysis

This describes the moments and the forces that cause the joint and limb motion. Kinetic data are obtained by quantitative analysis only. Kinetic analysis provides the causes for the observed kinematics.

Ambulatory EMG

Surface electrodes are placed on lower limb muscles and the electromyograph is recorded which is incorporated with the corresponding kinetic and kinematic data simultaneously. These surface EMG electrodes are placed on the following pairs of muscles to study their activity during gait:

Hip: Extensors (Gluteus Maximus)

Flexors (Rectus Femoris)

Abductors (Tensor Fascia Lata)

Adductor (Adductor Longus)

Knee: Extensor (Vastus Lateralis)

Flexor (Semimembranous)

Ankle: Dorsiflexor (Tibialis anterior)

Plantarflexor (Gastrosoleus)

Averaged EMG signals from these muscles are amplified near the surface electrode and again in a common box strapped to the subject's back before being sent down a fine wire to the main amplifiers from where it is sent to the computer for storage, analysis and display (36).

Physiological Cost Index

The energy cost of ambulation is traditionally estimated by measuring oxygen consumption and carbon dioxide production in a metabolic cart. A less accurate but easier method is to use the Physiological Cost index as an estimate of the energy cost of ambulation. This is calculated from the following formula:

$$\text{PCI} = \frac{\text{Walking HR} - \text{resting HR}}{\text{Walking speed in m/min.}}$$

Materials and Methods

The subjects for the study were children and young adults with cerebral palsy who had undergone Single Event multilevel Surgery for spasticity reduction and deformity correction between 2001 and 2003 at the Physical Medicine and Rehabilitation department of Christian Medical College Vellore. These children have been under the interdisciplinary care of the PMR department prior to surgery and had undergone observational and Instrumented gait analysis pre and post-operatively. Their clinical details and gait analyses were retrospectively analyzed.

The children had undergone various other procedures such as serial casting along with physical and occupational therapies prior to surgery. They had been started on medication for spasticity reduction after assessment by the interdisciplinary team.

Gait Analysis was done in the Gait Lab at the Rehabilitation Institute of the Christian Medical College Vellore.

Instrumentation for Gait Analysis

VIDEO GAIT RECORDING

A VHS format Panasonic video camera was used to record video gait records. At least two anteroposterior and lateral recordings each to be made for each side - one at full length view and one close up.

KINEMATIC DATA COLLECTION

The Selspot kinematic system was used for collection of kinematic data. This system uses infrared light emitting diodes (LEDs) as markers Fig4:1. These are connected at the patient's side to a light control unit which in turn connects to a long wire to the Administrating Unit at the computer area. This connects to the analogue digital card in the PC.

Fig 4:1- Position Of the LED markers on the lower limb, Courtesy of Gait Lab, Christian Medical College Vellore.

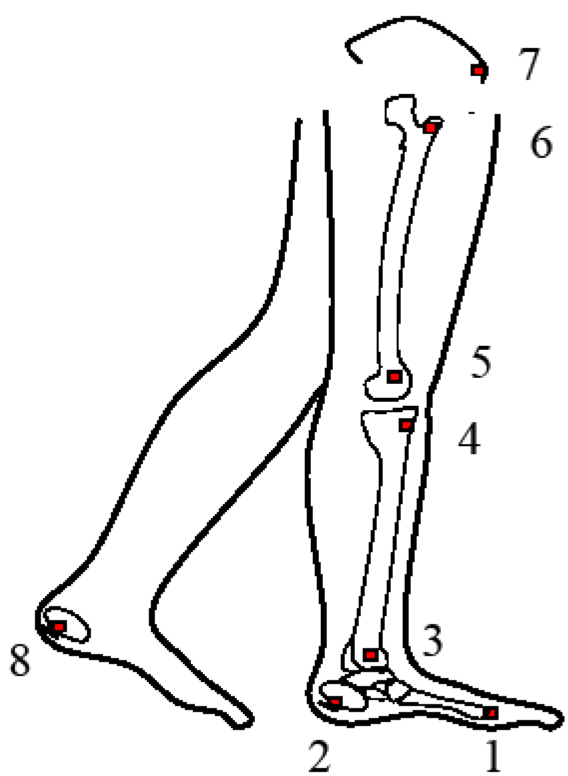


Fig 4:2 LED markers on the lower limb of a child (Courtesy of Gait Lab, Christian Medical College Vellore.)

There are 8 LEDs which are taped on to standardized bony prominences as follows:

LED 1 - head of 5th metatarsal

LED 2 - lateral prominence of heel

LED 3 - lateral malleolus

LED 4 - fibular head

LED 5 - lateral epicondyle of femur

LED 6 - anterior border of greater trochanter

LED 7 - Anterior superior iliac spine (ASIS) (previously iliac crest)

LED 8 - opposite foot - head of 1st metatarsal - helps in establishing single limb support

Fig 4:3- Courtesy Gait Lab Christian Medical College Vellore: Before data collection the position of the cameras in the room are defined from a fixed point in the room with a set of 4 LEDs on a standardized frame called the *Position Reference Structure (PRS).*

Kinematic outputs were standardized: stick figure, angular velocity and angular displacements in the sagittal plane at the hip, knee and ankle against distance and against time. Software was developed to automate stance- swing marking based on the velocity of LED 2, calculations and measurements like stride length, stride time, percentage of stance and swing, walking speed and cadence. Stride length was normalised with effective leg length. Single limb support, iliac crest displacement and Trendelenberg were calculated manually from print outs.

KINETIC DATA COLLECTION

The walkway has a Kistler force plate camouflaged in the middle, which the child walks on during the analysis. The force plate records the forces and this Is connected to a charge amplifier at the computer area. The patient should be able to have a single foot strike on the force plate without prior knowledge of this requirement to ensure optimal analysis.

DYNAMIC ELECTROMYOGRAPHIC DATA COLLECTION

Surface electrodes with preamplifiers are connected to the patient interface and transmitter unit on the patient's side. These electrodes need to be strapped firmly over the muscles. Fig4:4

This, like the light control unit, is connected by a long wire to filter, control and display units at the computer area. This then connects to the analogue digital card in the PC.

Fig 4:4 Child with Surface EMG electrodes in place (courtesy Gait Lab Christian Medical College Vellore

)

ENERGY CONSUMPTION DATA COLLECTION

Heart rate recordings at rest and after walking for 20 meters were obtained by placing one of the surface EMG electrodes on the chest. PCI was measure by dividing the difference in heart rate by the distance walked in meters per minute.

Stastical Methods:

The kinematic and the kinetic data for 26 limbs (13 children) pre op and post op were analysed.The average for each group was calculated with standard deviation. The data were normally distributed and hence difference between the pre and post op averages was tested for statistical significance using students T test and T Distribution using the Microsoft Excel programme.

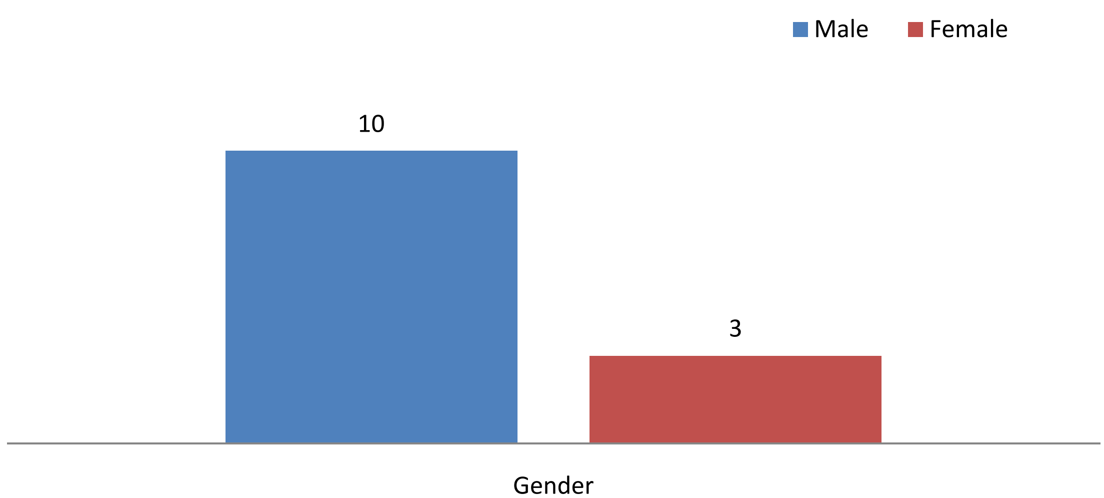
Results

Demographic Data:

Sex Distribution

The kinetic and kinematic study of a total of 13 children (26 Limbs) was done prior to and after SEMLS. 76.9% were males and 23.1% were females.

Fig 5:1- SEX OF SUBJECTS



Age of Pre-op Gait Analysis

The age of the children and young adults ranged between 4 and 23 years with a median of 9 and mean of 10.23. (Table 5:1)

Age of Pre-op Gait Analysis

Table 5:1

	Age of Pre Op Gait Analysis in Years
MEDIAN	**9**
RANGE	**4-23**
MEAN	**10.23**

Age of Post-op Gait Analysis

The follow up analysis of gait was done at an average of 2.33 years (range of 1 to 4 years). The age range of the subjects during the second evaluation was 6 to 24 years with a mean of 12.46 years.(Table 5:2)

Age of Post-op Gait Analysis- cont…

Table 5:2

	Age of Post- Op Gait Analysis in Years
MEDIAN	**11**
RANGE	**6-24**
MEAN	**12.46**

Table 5:3

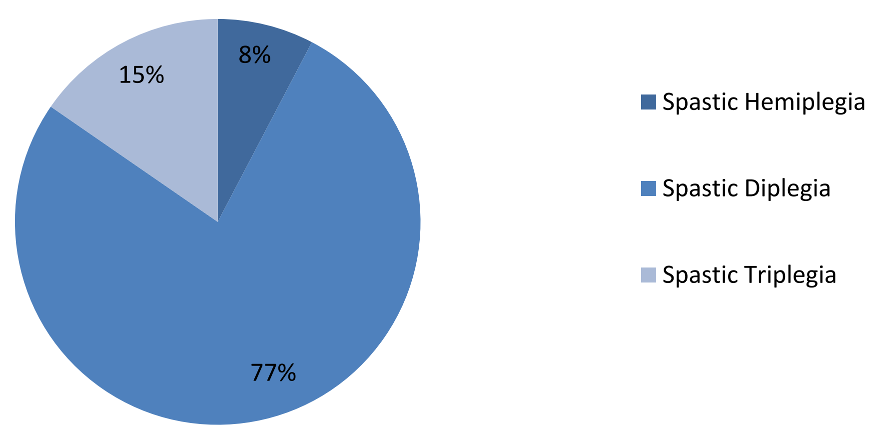
	Average duration between Gait Analyses in Years
MODE	**1**
RANGE	**1-4**
MEAN	**2.33**

Classification of The Study Population

Grouping Based on Topography

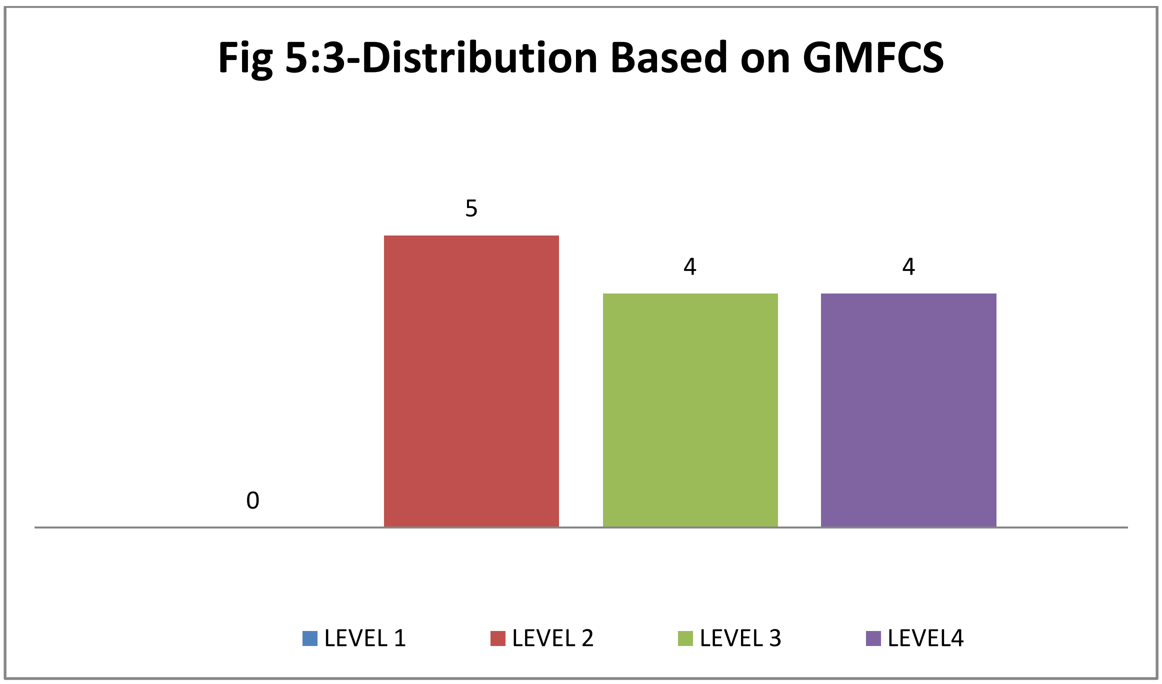
Of the 13 children and young adults analysed 77% were spastic diplegic, 15 % were spastic triplegic and the remaining 8% were spastic hemiplegic.

Figure 5:2 -Distribution Based On Topographic Diagnosis



Distribution Based on GMFCS

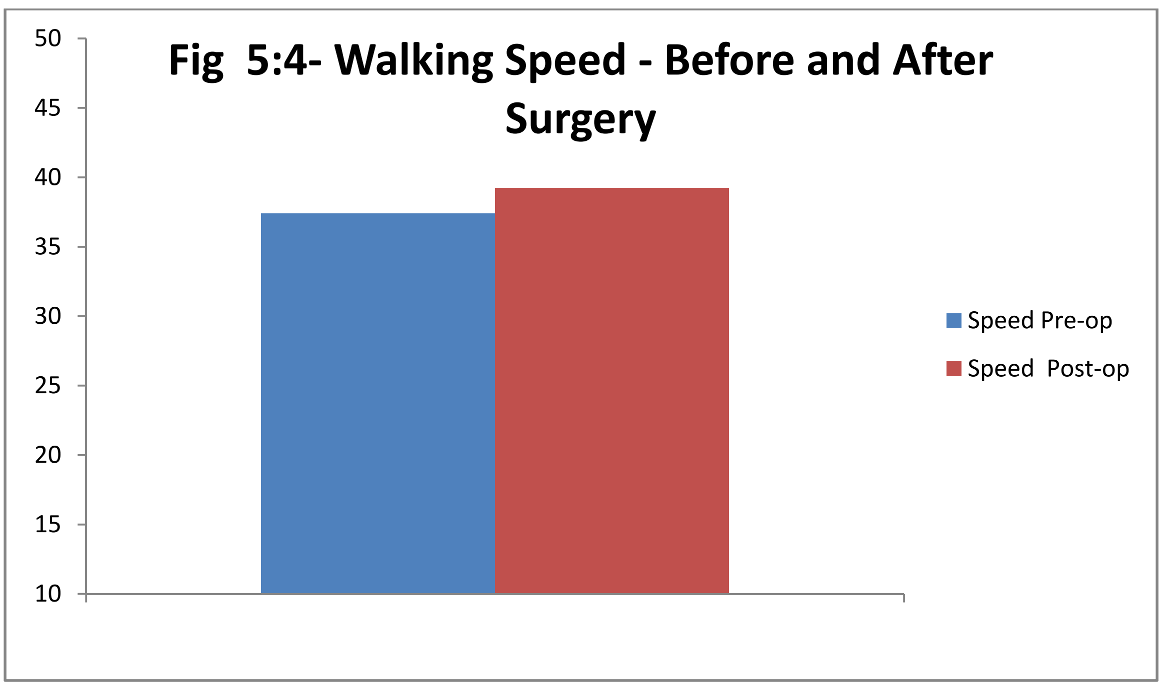
In the GMFCS none of them were in level 1. 5 of them had attained level 2 and 4 were in level 3 and 4 at the time of the initial pre-op gait analysis.



Kinematic Results

Walking Speed

A comparison of the average pre-op and post-op walking speeds showed an increase. There was however no statistically significant variation to attribute the change to the intervention. P=0.7



Stride Length

Stride length, normalized with height of individuals was found to be unchanged.

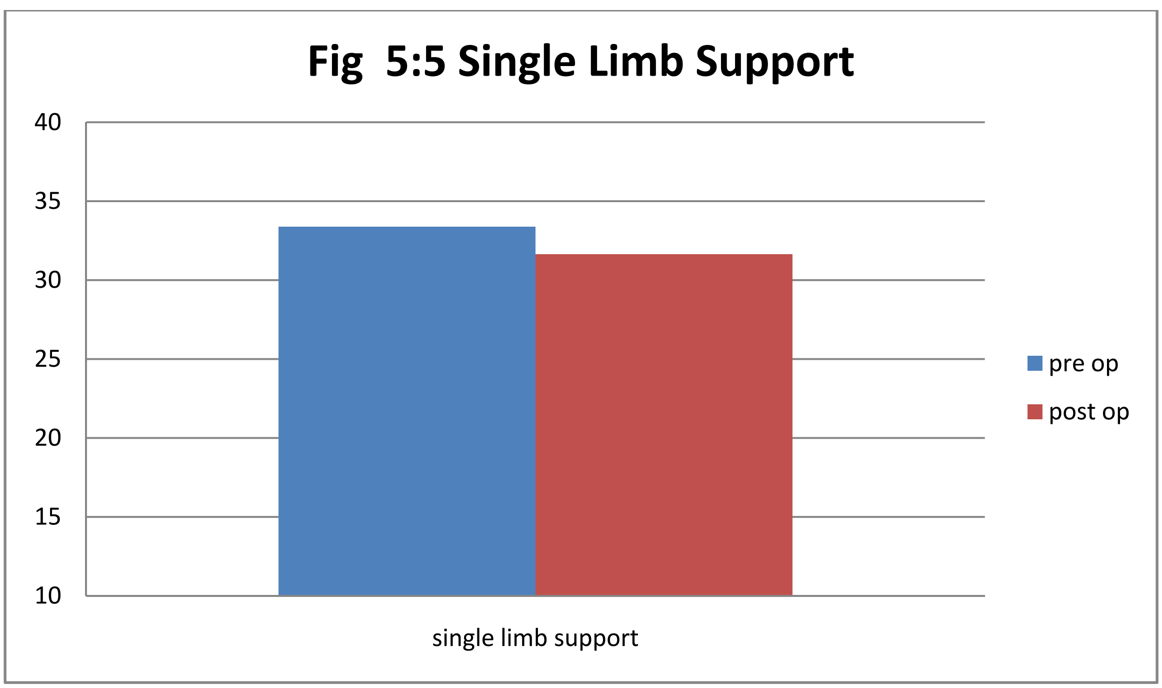
Table 5:4

Stride length pre-op	Stride length post op
0.61	0.6

Single Limb Support

The average single limb support of the subjects was reduced from 33.39% to 31.64%

(Fig5:5)

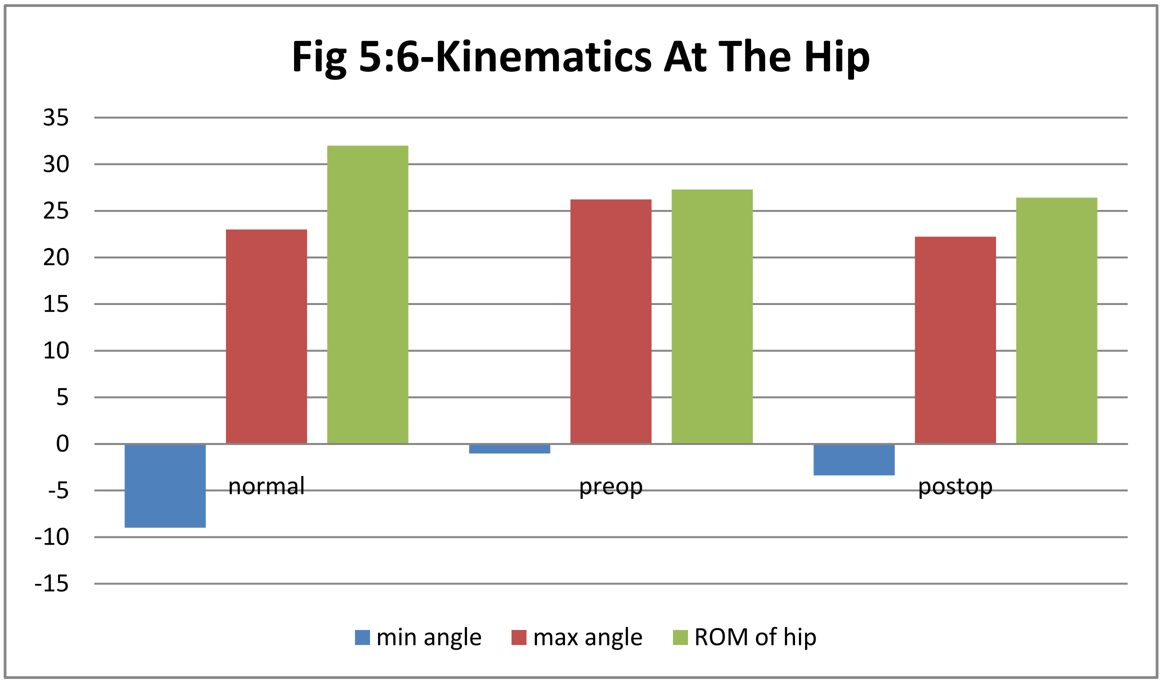


Kinematic variations at the Hip

There was an increase in hip extension at stance and reduction in hip flexion at swing. Data for normal children, published by Dr Ashish Macaden(39) has been compared in the table 5:5 and figure5:6.

Table 5:5

Angle	*Normal (In degrees)*	*Pre-op (In degrees)*	*Post op (In degrees)*	**P value**
Min hip angle in stance	**-9**	**-1.03**	**-3.38**	**0.8**
Max hip flexion angle in swing	**23**	**26.23**	**22.23**	**0.9**
ROM of the hip	**32**	**27.3**	**26.42**	**0.6**



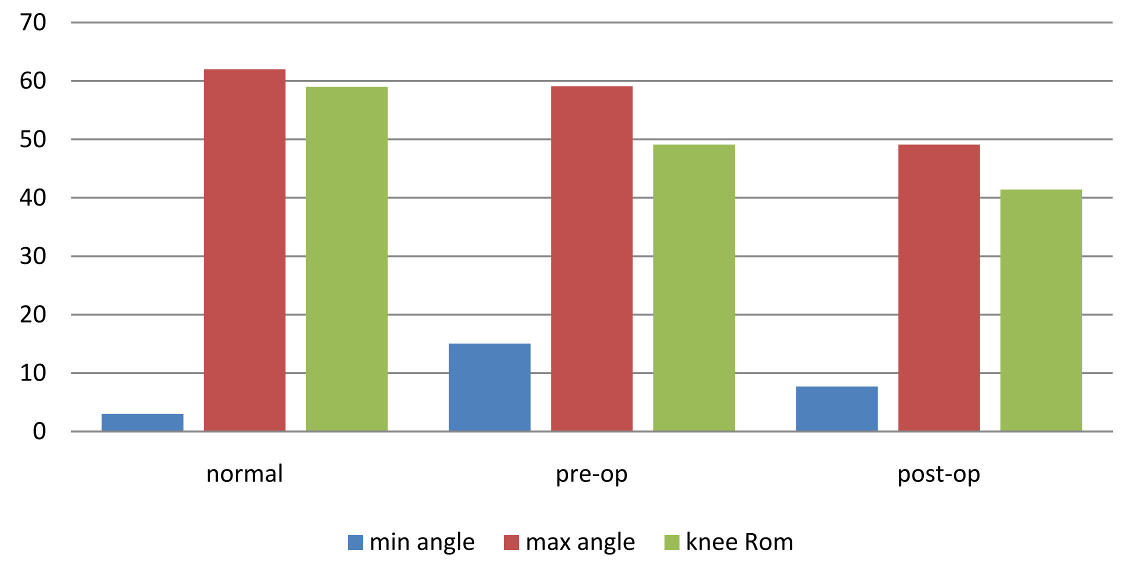
Kinematic Results at the Knee

The minimum knee flexion at stance had reduced from 15.03 to 7.7 degrees on an average and the maximum knee flexion at swing from 59 to 49 degrees. The ROM was reduced by 4degrees. The changes however were not significant statistically. Table 5:6, Fig 5:7.

Table 5:6

	Normal (In degrees)	*Pre-op (In degrees)*	*Post op (In degrees)*	P value
Min Knee angle in stance	**3**	**15.03**	**7.7**	**0.9**
Max Knee angle in swing	**62**	**59.1**	**49.1**	**0.9**
ROM of the Knee	**59**	**45.2**	**41,4**	**0.8**

Fig 5:7-Kinematics At The Knee



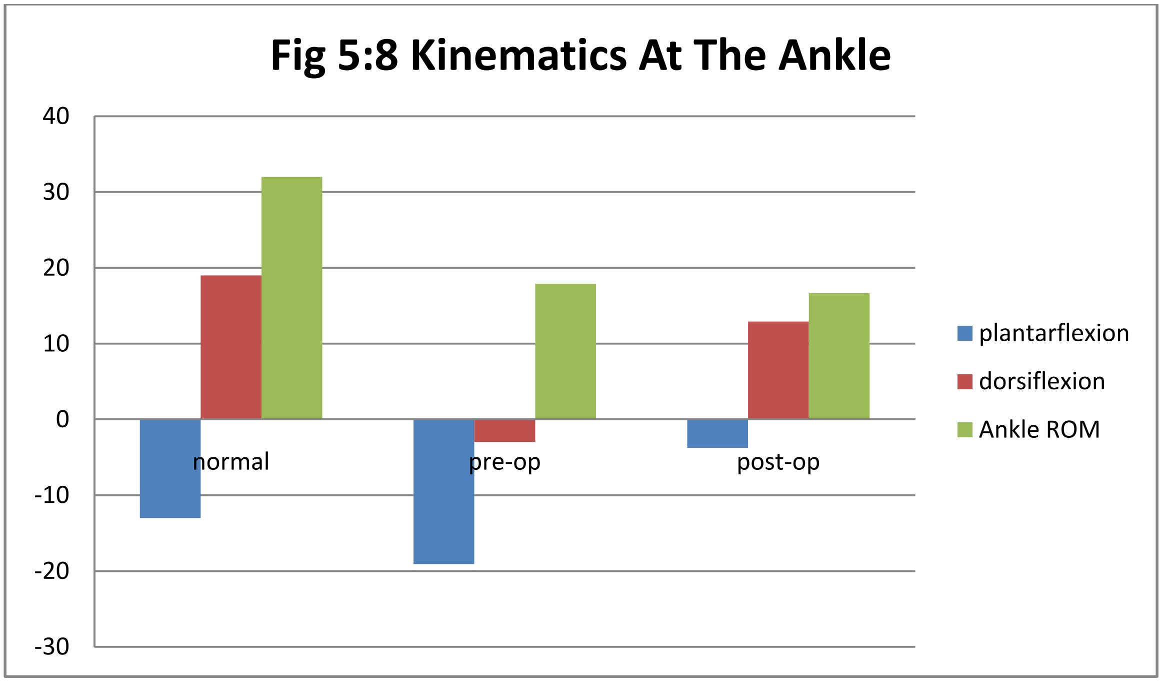
Ankle Kinematics Pre and Post op

There was reduction in the plantar flexion post op and increase in dorsiflexion in the analysis following surgery with an increase in the Range of Movement of the ankle. Fig 5:8, Table 5 :7 show data from pre op and post op ankle kinematics compared with a previous study by Dr Ashish Macaden. (39)

Ankle Kinematics Pre and Post op cont….

Table 5:7

	Normal (In degrees)	***Pre-op (degrees)***	***Post op (In degrees)***	**P value**
Plantarflexion angle	**-13**	**-19.07**	**-3.75**	**.9**
Dosiflexion angle	**19**	**-2.96**	**12.92**	**.9**
ROM of the ankle	**32**	**7.91**	**16.67**	**.5**



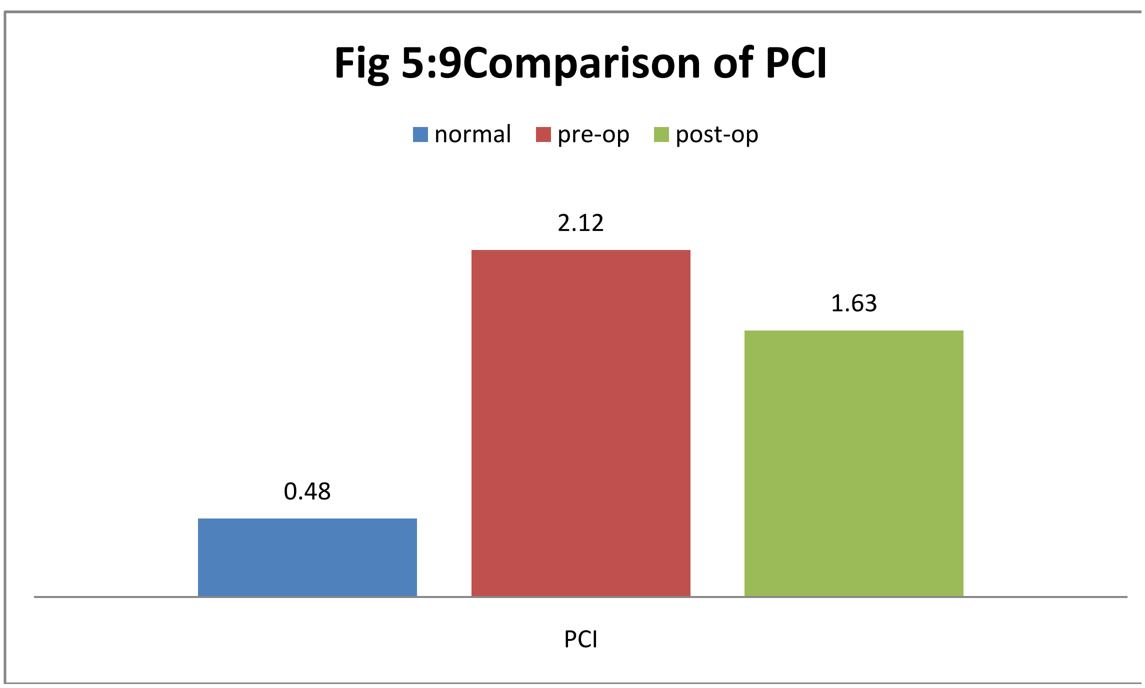
Physiological Cost Index

The PCI had dropped post –op but the p value was not low enough to point to statistical significance. The PCI pre op and post op has been compared with the PCI of normal children from Dr Ashish Macaden’s study (39) Table 5:8, Fig 5:9

Table 5:8

PCI	*Normal*	*Pre-op*	*Post op*	**P value**
	0.48	2.12	1.63	**.75**

PCI = (Post exercise HR - resting HR) / average walking speed in meters/min)



Kinetic Data

Change in Vertical Forces Normalized by Body Weight

Change In Vertical Forces normalized by body weight was compared with the post operative data. There was no statistically significant difference though there was a reduction in the post –op average Fig 5:9

Table 5:9

	Pre-op	***Post op***	**P value**
Vertical Force Normalized with body weight (normal children- 115 +/-19)	123.46	108.61	**0.9**

Change in Forward Forces Normalized by Body Weight:

Table 5:10 shows he comparison of forward forces normalized by body weight of the children and young adults studied. The difference was not statistically significant (p value 0.82)

Table 5:10

	Pre-op	***Post op***	**P value**
Forward Force Normalized with body weight (Normal children16.5=/-6)	17.07	15	**0.82**

Change in Backward Forces Normalized by Body Weight

The post op average of backward forces were less than the pre-op value but with no significance statistically. Table 5:11

Table 5:11

	Pre-op	***Post op***	**P value**
Backward Force Normalized with body weight N/kg	12.3	9.9	**.96**

Change in Medial Forces Normalized by Body Weight:

Medial Forces were reduced post operatively, The difference was not of statistic significance p=0.99. Table 5:12

Table 5:12

	Pre-op	***Post op***	**P value**
Medial Force Normalized with body weight N/kg	5.19	3.26	**0.99**

Change in Lateral Forces Normalized by Body Weight

An increase in post operative average of lateral force normalized by weight was not. The p value was 0.58 Table 5:13

Table 5;13

	Pre-op	*Post op*	P value
Lateral Force Normalized with body weight (35+/-19)	9.7	10.03	**0.58**

Change in Functional Level

The functional evaluation of the children post operatively showed changes in 4 of the 13 subjects in the GMFCS. 2 had progressed to level 1 from levels 4 and 2, post;op. two to level 2 from level3. Fig 5:

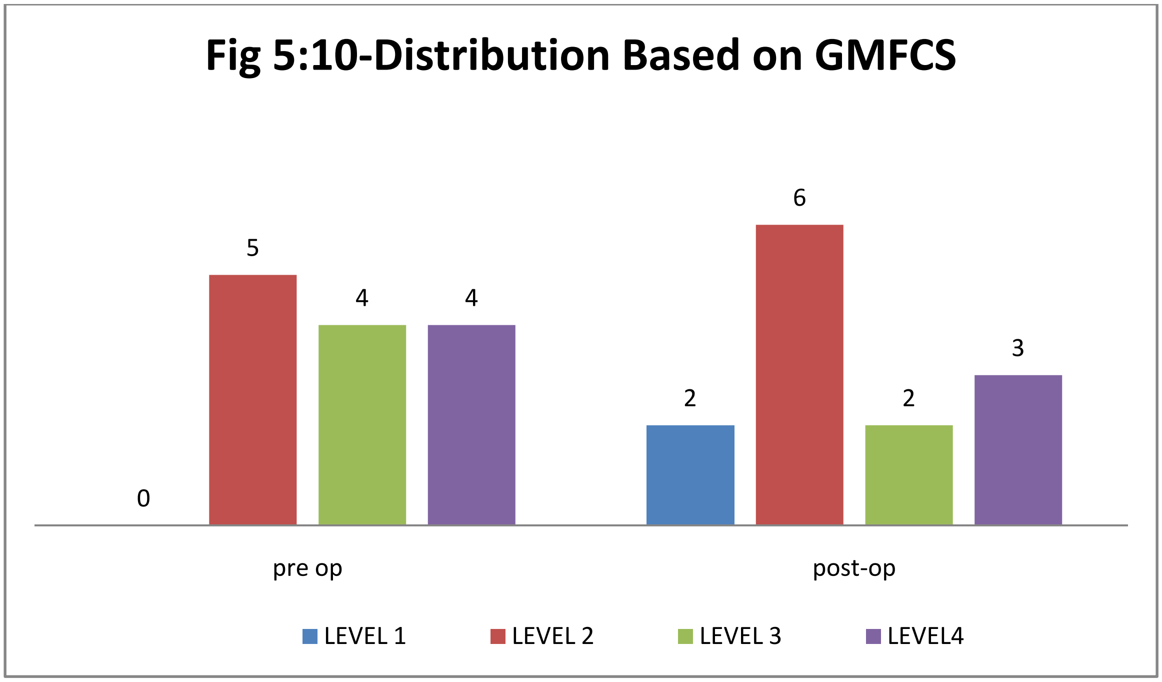


Fig 5:10-Distribution Based on GMFCS
0
5
4
4
2
6
2
3
pre op
post-op
LEVEL 1
LEVEL 2
LEVEL 3
LEVEL4

Discussion

Cerebral Palsy is described as a “*static encephalopathy*”(4), but the musculoskeletal pathology is progressive (11). The natural history of gait and function of six to twelve-year-old children with cerebral palsy is progressive deterioration (38)

The most important pathological feature of the progressive musculoskeletal pathology is a failure of longitudinal growth of skeletal muscle. An apt orthopedic synonym for CP is ‘*short muscle disease’* (11). The normal muscle grows due to regular stretching under conditions of physiological loading, when it is relaxed. Spasticity in Children with CP prevents the skeletal muscle from relaxing during activity and also greatly reduces the levels of activity due of muscle weakness and poor balance.
Contractures result due to imbalance between growth of long bones and the muscle tendon unit. This has been demonstrated in animal models by Ziv et al (12) and further confirmed by Cosgrove and Graham (13).During the past twenty years, increasing emphasis has been placed on the correction of all fixed musculoskeletal deformities with single-event multilevel surgery (38).

The primary goal of single-event multilevel surgery in children with cerebral palsy is to improve gait. Secondary goals may include improvements in gait efficiency (30) (38) and appearance, gross motor function, independence, and quality of life (38).

At the Physical Medicine and Rehabilitation Department of Christian Medical College, Vellore, Single Event Multilevel Surgeries have been in regular practice, along with other modalities of treatment, in an interdisciplinary team of therapists, orthotists and physiatrists. Children and young adults were on regular follow up over various time spans had a treatment programme tailored to their physical and various other needs. Apart from SEMLS, they received serial casts, nerve blocks, Botulunium toxin injections, anti-spasticity medication, orthoses, physical, occupational, and Speech and language therapies. The team was well convinced of the positive results of SEMLS but objective evidence was lacking from the Institution to validate our claim. Though the advantages of SEMLS has been emphasized by various studies from different centers in our country and abroad, very few provide objective data analysis.

The advantages and popularity of orthopedic surgery as a part of management of musculoskeletal developmental irregularities, may gradually lose its due credit for lack of efficiently conducted data analysis and proof of changes shown in internationally accepted functional scales as recommended by the ICF (18) (26).

Hence a retrospective analysis of existing data was decided upon as a forerunner for a randomized control trial in future.

The retrospective data between 2001 and 2006 of children who had completed a minimum of 12 months after SEMLS and had followed up for a full instrumented gait analysis following and prior to surgery showed a gender asymmetry of 77% males and 23% females. This when compared with Dr Mcaden's data of 62% males and 38% females shows a trend in the society of negligence and discrimination of the disabled girl child who hardly reaches a specialized centre. This subject of the missing disabled girl children needs to be addressed. However the author prefers not to elaborate on this as this is beyond the scope of this study.

Functional Classification using the GMFCS showed change in 3 children out of the 13. There was a marginal increase in the walking speed of the children following the surgical intervention, though not statistically significant. The single limb support expressed in percentage of the gait cycle, a measure of the stance phase stability was reduced post op. This could be an indicator of decreased balance post procedure but in view of the small sample size and lack of statistical significance in the difference, further studies with a larger sample size and better design are suggested

The maximum hip extension at stance was increased by an average of 2 degrees. Range of hip movement was reduced. There appears to be less of hip flexion though no statistical significance was observed. The knee flexion at stance was less by 7 degrees on an average and the range of the knee was reduced too. The equinus at the ankle was corrected (average value) and the dorsiflexion range was better post –op yet with no statistical significance. To summarize on the kinematic data variations following SEMLS shows favorable changes though the variation has no ststistical significance.

The PCI was less in the postoperative analysis but still much higher as compared with the normal value of 0.48. There was again no statistical significance in the difference.

The vertical and mediolateral forces have reduced post op but lies well within the value for normal children. The lateral force is much less as compared to normal children and has reduced post-top. The low lateral force could be due to valgus at the ankle.

The advantage of this study is the comparison of objective quantification from Kinematic and kinetic evaluation.

The primary disadvantage of the study was its retrospective design. A prospective follow-up study or a randomized control study is recommended. The small sample size of 26 limbs is another disadvantage.

SEMLS was one among the many interventions the subject had undergone. Data regarding the intensity of therapy and the strict observance of prescription drugs could not be obtained. The possibility of the child having received indigenous treatment could not be ruled out.

Conclusions

1. Instrumented Gait Analysis data in the sagittal plane showed a positive variation in kinematics of the hip, knee and ankle but the evidence was not of statistical significance.
2. The energy efficiency of gait following SEMLS was better but the difference in the reduction of the PCI was not statistically significant.
3. A prospective study such as a randomized controlled study is urgently required with the adequate sample size is recommended.

Bibliography

1. Frank M. Chang, MD Jason T. Rhodes, MD, MS , Katherine M. Flynn, BA , James J. Carollo Role of Gait Analysis in Treating Gait Abnormalities in Cerebral Palsy, Orthopedic Clinics of North America Volume 41, Issue 4, Pages 489-506, October 2010

2. Weil E, Wachterman M, McCarthy E, Davis R, O'Day B, Lezzoni L, Wee C. Obesity among adults with disabling conditions. *J Am Med Assoc.* 2002;**288**:1265–1268. doi: 10.1001/jama.288.10.1265.
3. Molnar GE. (1985) Cerebral palsy. In: Molnar GE, editor. *Pediatric Rehabilitation.* Baltimore, Williams and Wilkins,1985, pp481-533.
4. Nelson Textbook of Pediatrics, ed 14 WB Saunders 1992 sec 20.49. p. 1515.
5. Rosenbaum P, Paneth N, Leviton A, et al. A Report: the definition and classification of cerebral palsy April 2006. Dev Med Child Neurol Suppl 2007; 109:8.
6. James R Gage MD, Barry S Russman. Gait Analysis in Cerebral Palsy: Clinics in Developmental Medicine No121. London: Mac Keith Press, 1991. p.1
7. Dunn P, Dr William Little (1810-1894) of London and cerebral palsy. *Arch Dis Child Fetal Neonatal Ed*. 1995 May; 72(3): F209–F210.
8. Freeman, J. and N. KB., Intrapartum asphyxia and cerebral palsy. Pediatrics, 1988. 82: p. 240-9

9. Bax MCO, Flodmark O, Tydeman C. Definition and classification of cerebral palsy. From syndrome toward disease. *Dev Med Child Neurol* (Suppl.) 2007; **109**: 39-41.
10. Einspieler C, Prechtl HF. Prechtl's Assessment of general movements: a diagnostic tool for the functional assessment of the young nervous system. *Ment Retard Dev Disabil* Res Rev. 2005; 11: 61-7.
11. Kerr Graham H, Selber P, Musculoskeletal aspects of cerebral palsy .*J Bone Joint Surg Br*. 2003 Mar;85(2):157-66.
12. Ziv I, Blackburn N, Rang M, Koreska J. Muscle growth in normal and spastic mice. *Dev Med Child Neurol* 1984;26:94-9.
13. Cosgrove AP, Graham HK. Botulinum toxin A prevents the development of contractures in the hereditary spastic mouse. *Dev Med Child Neurol* 1994;36:379-85.
14. Brown JK, Minns RA. Mechanisms of deformity in children with cerebral palsy. *Seminars in Orthopaedics* 1989 Vol 14 No 4:236-55.
15. Miller F, Dabney KW, Rang M. Complications in cerebral palsy treatment. In: Epps CH, Bowen JR, eds. Philadelphia. JB Lippincott Co.*Complications in pediatric orthopaedic surgery* 1995;23.
16. Andersson C, Mattsson E. Adults with cerebral palsy: a survey describing problems, needs and resources, with special emphasis on locomotion. *Dev Med Child Neurol* 2001;43:76-82.

17. Graham, H. Kerr MD, Editor(s): Stanitski, Carl L. MD, Classifying Cerebral Palsy, Journal of Pediatric Orthopaedics: January/February 2005 - Volume 25 - Issue 1 - pp 127-128

18. World Health Organization. International Classification of Functioning, Disability and Health. Geneva: World Health organization; 2001.

19. Palisano R, Rosenbaum P, Walter S et al. Development and Reliability Of A System To Classify Gross Motor Function In Children With Cerebral Palsy. *Dev Med Child Neurol*. 1997;39:214-223.

20. Palisano RJ, Rosenbaum P, Bartlett D, Livingston MH. Content Validity of the Expanded and Revised Gross Motor Function Classification System. *Dev Med Child Neurol* 2008;50:744–750

21. Graham HK, Harvey A, Rodda J, Nattrass GR, Pirpiris M , The Functional Mobility Scale (FMS); *J Pediatr Orthop.* 2004 Sep-Oct; 24(5):514-20.

22. TF Winters, JR Gage and R Hicks, Gait patterns in spastic hemiplegia in children and young adults: *J Bone Joint Surg Am.* 1987;69:437-441.

23. Sutherland DH, Davids JR (1993). Common gait abnormalities of the knee in cerebral palsy. Clin Orthopaedics Related Res 288:139±147.

24. Rodda J, Graham HK**.** Classification of gait patterns in spastic hemiplegia and spastic diplegia: a basis for a management algorithm. *Eur J Neurol* 2001;8:S98-

25. Miller F, Dabney KW, Rang M**.** Complications in cerebral palsy treatment. In: EppsCH Jr, Bowen R, eds. *Complications in pediatric orthopaedic surgery.* Philadelphia, JB Lippincott Company, 1995;477:477-544.

26. H. Kerr Graham H K, ORTHOPAEDIC SURGERY IN THE MANAGEMENT OF CEREBRAL PALSY,*Recent Developments in Healthcare for Cerebral Palsy: Implications and Opportunities for Orthotics Report of a meeting held at Wolfson College, Oxford,* 8-11 September 2008
27. Rang M, Silver R, De La, Garza J. Cerebral palsy. In: Lovell WW, Winter RB (eds) Pediatric Orthopaedics, 2ndEdin, Vol 1. Philadelphia: JB Lippincott, 1986.
28. Gage JR (Editor) The Treatment of Gait Problems in Cerebral Palsy. Clinics in Developmental Medicine No 164-165. Mac Keith Press. London. 2004.
29. Norlin R, Tkaczuk H. One-session surgery for correction of lower extremity deformities in children with cerebral palsy. *J Pediatr Orthop* 1985;5:208-211.
30. Nene AV, Evans GA, Patrick JH. Simultaneous multiple operations for spastic diplegia. *J Bone Joint Surg* 1993;75-B:488-494
31. Gage JR, Fabian D, Hicks R, Tashman. Pre- and postoperative gait analysis in patients with spastic diplegia: A preliminary report. J Pediatr Orthop 1984: 715-725.
32. Richard Baker, The history of gait analysis before the advent of modern computers, Gait & Posture. 2007; 26,3:331-474
33. Muybridge E: Animal Locomotion: An Electro-Photographic Investigation of Consecutive Phases of Animal Movements. Philadelphia, Published under the auspices of the University of Pennsylvania,1887

34. **Esquenazi A ;Randall L. Braddom,** Physical Medicine & Rehabilitation; W B Saunders Title; 2 edition,Page93

35. Perry J et al, Observational Gait Analysis Handbook, Ranchos Los Amigos Medical Centre.

36. Ganesh T, Bhuvaneshwar N, Chilman R, Tharion G, Devasahayam S, Bhattacharji S, Gait Analysis : an Overview. Department of Physical Medicine and Rehabilitation, Christian Medical College, Vellore

37. Macaden A et al, What Gait Analysis Tells us About Clinical Examination of Spastic Gait in Children. IJPMR October 2005; 16 (2): 45-47

38. Pamela Thomason, Richard Baker, Karen Dodd, Nicholas Taylor, Paulo Selber, MD, FRACS5; Rory Wolfe, H. Kerr Graham, *Single-Event Multilevel Surgery in Children with Spastic Diplegia: A Pilot Randomized Controlled Trial* *J* Bone Joint Surg Am. 2011; 93:451-460

39. Macaden A. *et al* A Descriptive Study Of Gait Analysis In The Sagittal Plane Of Children With Cerebral Palsy. Christian Medical College Vellore.

Appendix

Data Entry (Microsoft Exel File)

Sno	name	number	agepre	agepost	Diag	GMFCS pre	GMFCS pos	gend	pre GA
1	Abhik Das	549907B	7	11	Spastic Diplegia	3	2	m	17/09/1999
2	Abhik Das	549907B	7	11	Spastic Diplegia			m	17/09/1999
3	Abhik Das	549907B	7	11	Spastic Diplegia			m	17/09/1999
4	Abhik Das	549907B	7	11	Spastic Diplegia			m	17/09/1999
5	Anwesh chakraborthy	890943B	7	11	Spastic R hemi	2	2	m	31/5/2001
6	Anwesh chakraborthy	890943B	7	11	Spastic R hemi			m	31/5/2001
7	Shatanik Bhattacharyya	721758B	8	10	Spastic diplegia	2	2	m	########
8	Shatanik Bhattacharyya	721758B	8	10	Spastic diplegia			m	########
9	Mrinansarkar	161173C	5	6	Spastic Diplegia	2	2	F	22/05/2002
10	Mrinansarkar	161173C	5	6	Spastic Diplegia			F	22/05/2002
11	Dinesh Kumar	547635B	12	13	Spastic Diplegia	3	2	M	19/05/03
12	Dinesh Kumar	547635B	12	13	Spastic Diplegia			M	19/05/03
13	Harish Kumar	490451B	9	11	Spastic Diplegia	3	3	M	########
14	Harish Kumar	490451B	9	11	Spastic Diplegia			M	########
15	Suprava Chakraborthy	758153B	19	22	Spastic Triplegia	2	2	M	25/05/01
16	Suprava Chakraborthy	758153B	19	22	Spastic Triplegia			M	25/05/01
17	Pamella Das	064930C	12	13	Spastic Triplegia	2	1	F	28/11/02
18	Pamella Das	064930C	12	13	Spastic Triplegia			F	28/11/02

19	Keya Maity	106561C	9	11	Spastic Diplegia	3	3	F	19/8/02
20	Keya Maity	106561C	9	11	Spastic Diplegia			F	19/8/02
21	Debashis Bhallav	300860B	8	12	Spastic Diplegia	4	1	M	22/3/00
22	Debashis Bhallav	300860B	8	12	Spastic Diplegia			M	22/3/00
23	Biswajit Saha	680104B	4	6	Spastic Diplegia	4	4	M	17/3/00
24	Biswajit Saha	680104B	4	6	Spastic Diplegia			M	17/3/00
25	Kaushal Chandrakumar	270925C	23	24	Spastic Diplegia	4	4	M	26/2/03
26	Kaushal Chandrakumar	270925C	23	24	Spastic Diplegia			M	26/2/03
27	Linkon	854602B	10	12	Spastic Diplegia	4	4	M	13/9/02
28	Linkon	854602B	10	12	Spastic Diplegia			M	13/9/02

limb	intervention	final GA	spd pre	sdp post	slspre	slspost	std pre	Stdpost	ssratiopre
r	semst13/10/99	27/05/02	36	53	38	41	64(.55)	86(.64)	57;43
r afo	afovs semstaafo	27/05/02	43	65	42	40	75 (.64)	103(.75)	57;43
L	semst	27/05/02	60	44	39	36	93(.81)	70(.53)	50;50
Lafo	afovs semstaafo	27/05/02	47	53	40	41	76(.65)	90(.66)	53;46
r	semst21/06/01	########	45	47	41	40	76(.64)	82(.61)	48;52
L	semst21/06/01	########	57	53	42	41	79(.66)	93(.70)	49;51
R	semst16/06/04)	22/05/06	38	45	33	40	61(.52)	76(.6)	63;35
L	semst16/06/04)	22/05/06	37	45	31	38	63(.54)	76(.6)	59;41
R	semst29/05/02	########	38	48	37	23	70(.73)	49(.87)	55;45
L	semst29/05/02	########	48	23	39	24	84(.87)	49(.47)	53;47
R	semst11/06/03	6/5/2004	39	60	37	38	62(.45)	88	67;33
L	semst11/06/03	6/5/2004	46	66	41	39	74(.54)	76	61;39
R	semst15/5/02	4/3/2003	51	64	39	39	78(.63)	102(.77)	57;43
L	semst15/5/02	4/3/2003	60	68	45	41	84(.68)	108(.82)	56;44
R	semst6/6/01	########	58	56	41	41	114(.7)	99(.6)	56;44
L	semst6/6/01	########	59	55	38	37	103(.63)	109(.66)	51;49
R	semst4/12/02	17/11/03	42	29	35	29	76(.51)	65(.44)	61;39
L	semst4/12/02	17/11/03	40	29	38	33	76(.51)	65(.44)	60;40
R	semst20/8/02	15/9/04	45	42	44	32	63	80	56;44
L	semst20/8/02	15/9/04	40	26	41	25	60	66	61;39

R	semst29/3/00	########	13	30	25	35	37	60(.43)	80;20
L	semst29/3/00	########	14	30	37	34	30	62(.44)	79;21
R	semst22/3/00	16/7/02	2.89	12	2	11	35(.38)	47(.45)	97;3
L	semst22/3/00	16/7/02	3.48	4	10	10	26(.25)	23(.22)	94;6
R	semst26/2/03	5/2/2004	29	10	26	30	63	19	68;32
L	semst26/2/03	5/2/2004	37	14	25	19	69	22	49;51
R	semst18/9/02	########	9	12	15	13	25(.2)	41	84;16
L	semst18/9/02	########	10	16	14	16	29(.23)	44	83;17

ssratiopost	mnhapre	mxhanpre	hrompre	mnhapost	mxhanpost	hrompost	mnkapre	mxkanpre	krompre
65;38	-15	29	44	-7	19	26	17	58	41
57;43	-22	20	41	-7	24	31	1	71	70
56;44	-10	29	39	-3	19	22	3	71	68
61;39	-8	26	34	-3	24	27	2	76	72
62;38	-1	25	26	-8	9	17	14	65	51
61;39	-5	16	21	-5	17	22	16	52	36
62;38	-8	16	24	1	25	24	9	3	30
60;40	15	46	31	4	19	15	29	57	28
75;25	-12	26	38	-3	32	35	3	57	54
71;29	-5	40	45	10	30	40	1	57	56
58;42	-1	23	24	-5	20	25	10	62	52
57;43	2	31	29	-13	23	36	2	65	63
56;44	-3	24	27	-4	21	25	31	67	36
56;44	9	31	22	-3	27	30	34	72	38
61;39	-8	21	29	-7	30	37	18	62	44
58;42	6	29	23	-2	36	38	41	80	39
66;34	2	30	28	-3	27	30	21	55	34
69;31	0	27	27	-5	14	19	14	50	36
69;31	8	27	19	-10	30	40	29	49	20
74;26	9	28	19	-7	16	23	30	54	24
66;35	-7	9	16	-5	25	30	8	53	45
66;35	-1	18	19	-2	17	19	23	56	33
83;7	15	36	21	-20	10	30	14	73	59
89;11	-3	27	30	-5	34	39	7	82	75
82;18	3	16	13	0	0	0	26	58	32
73;27	13	32	19	24	31	7	16	77	61
81;19				-3	28	31	0	32	32
84;16				-7	16	23	2	41	39

mnkapo st	mxkapo st	krompo st	mnaanp re	mxaanp re	aromp re	mnaanpo st	mxaanpo st	arompo st	Wtpr e
1	55	54	-32	-4	28	-15	1	14	17.5
5	73	68	-3	13	16	-7	8	15	18
1	45	44	-21	-6	15	-3	14	17	17.5
-3	61	64	2	11	9	-4	13	17	18
8	54	46	-56	-30	26	-4	4	8	25
4	65	61	-7	3	10	-17	13	30	25
25	48	23	-15	-4	11	2	15	13	35
15	46	31	-54	-26	28	-8	6	14	3
0	59	59	-45	-20	25	-3	8	11	14
-6	46	52	-70	-33	37	-4	10	14	14
6	54	48	-3	6	9	-2	17	19	34.5
-2	42	44	3	10	7	6	16	10	34.5
24	60	36	8	16	8	5	21	16	26
18	64	46	6	12	6	-3	21	24	26
7	59	52	-21	-1	20	-5	9	14	52.5
26	69	43	-37	-12	25	-5	22	27	52.5
13	46	33	-32	-11	21	-2	14	16	49.5
4	33	29	-25	-7	32	-7	12	19	49.5
1	49	48	-29	-26	3	-4	16	20	21
-5	40	45	-37	-20	17	-4	20	24	21
9	45	36	-14	4	18	4	23	19	20
11	33	22	-50	-32	18	-4	16	20	20
0	45	45	-13	1	1	-15	2	17	15
2	15	13	16	31	15	-22	5	27	15
23	48	25	-3	13	16	1	8	7	50.5
20	43	23	-2	7	9	12	16	4	50.5
5	45	40	-4	8	12	0	14	14	22
4	34	30	4	14	10	3	18	15	22

wtpost	vforcepre	vforcepost	fforcepre	fforcepost	bforcepre	bforcepost	mforcepre	mforcepost	lforcepre
31.5	95	98	17	13	18	13	3	4	11
33	131	115	31	26	14	14	4	3	9
31.5	134	119	24	21	24	7	1	3	11
33	168	136	27	33	20	6	2	2	12
36	147	105	33	15	23	10	6	0	12
36	198	117	30	12	18	13	5	1	8
46	157	119	22	18	6	8	1	1	21
46	92	104	14	8	7	10	2	8	11
18	165	92	43	11	10	7	9	3	17
18	158	96	29	18	14	7	15	4	5
38	115	103	9	8	14	11	4	0	12
38	100	107	16	13	11	13	1	1	14
30	145	143	24	24	10	18	6	2	4
30	151	136	23	28	12	14	5	11	3
52.5	114	102	9	13	15	16	6	0	5
52.5	126	103	3	19	16	10	8	6	3
53	99	95	10	10	13	10	7	2	7
53	108	99	19	12	7	7	7	3	10
36.5	154	151	12	23	8	10	5	2	19
36.5	123	105	8	15	9	12	9	5	10
42	88	101	6	10	7	8	3	2	8
42	91	105	11	12	10	5	4	1	9
16									
16									
62	103	100	3	7	6	6	3	2	11
62	87	93	6	6	6	2	1	2	10
27	88	88	6	8	12	10	9	11	6
27	73	92	9	7	10	12	9	6	6

lforcepost	pcipre	pcipost
11	0.72	0.7
12	0.84	0.64
12	0.72	0.7
14	0.84	0.64
9	0.8	0.44
8	0.8	0.44
11	0.93	1.2
10	0.93	1.2
14	1.37	1.18
18	1.37	1.18
10	0.74	1.02
11	0.74	1.02
7	0.66	0.69
5	0.66	0.69
9	0.73	0.59
8	0.73	0.59
8	1.39	1.35
7	1.39	1.35
14	0.71	2.03
11	0.71	2.03
11	1.59	1.25
13	1.59	1.25
	16	5
	16	5
5	1.15	4.5
8	1.15	4.5
10	2.17	2.35
5	2.17	2.35